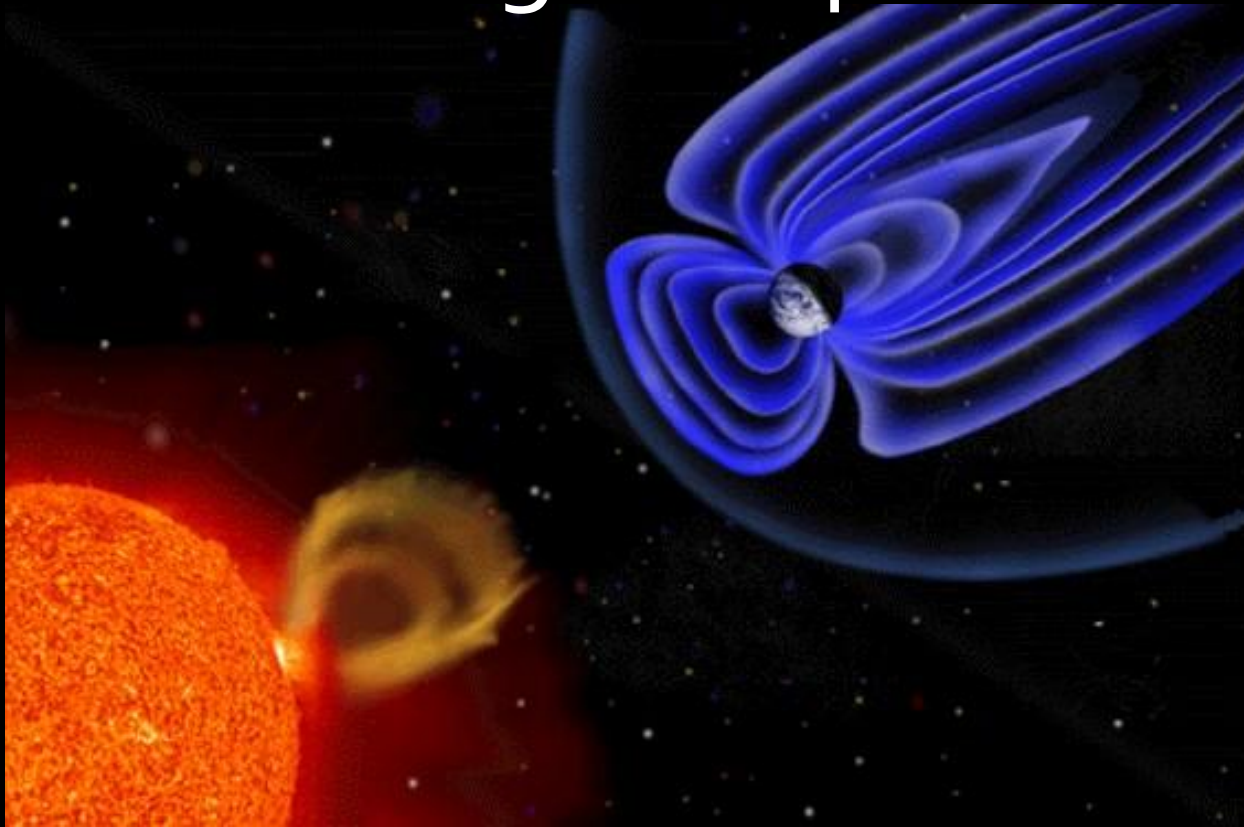


# Turbulence in the Magnetosheath: Solar Wind – Magnetosphere Interactions

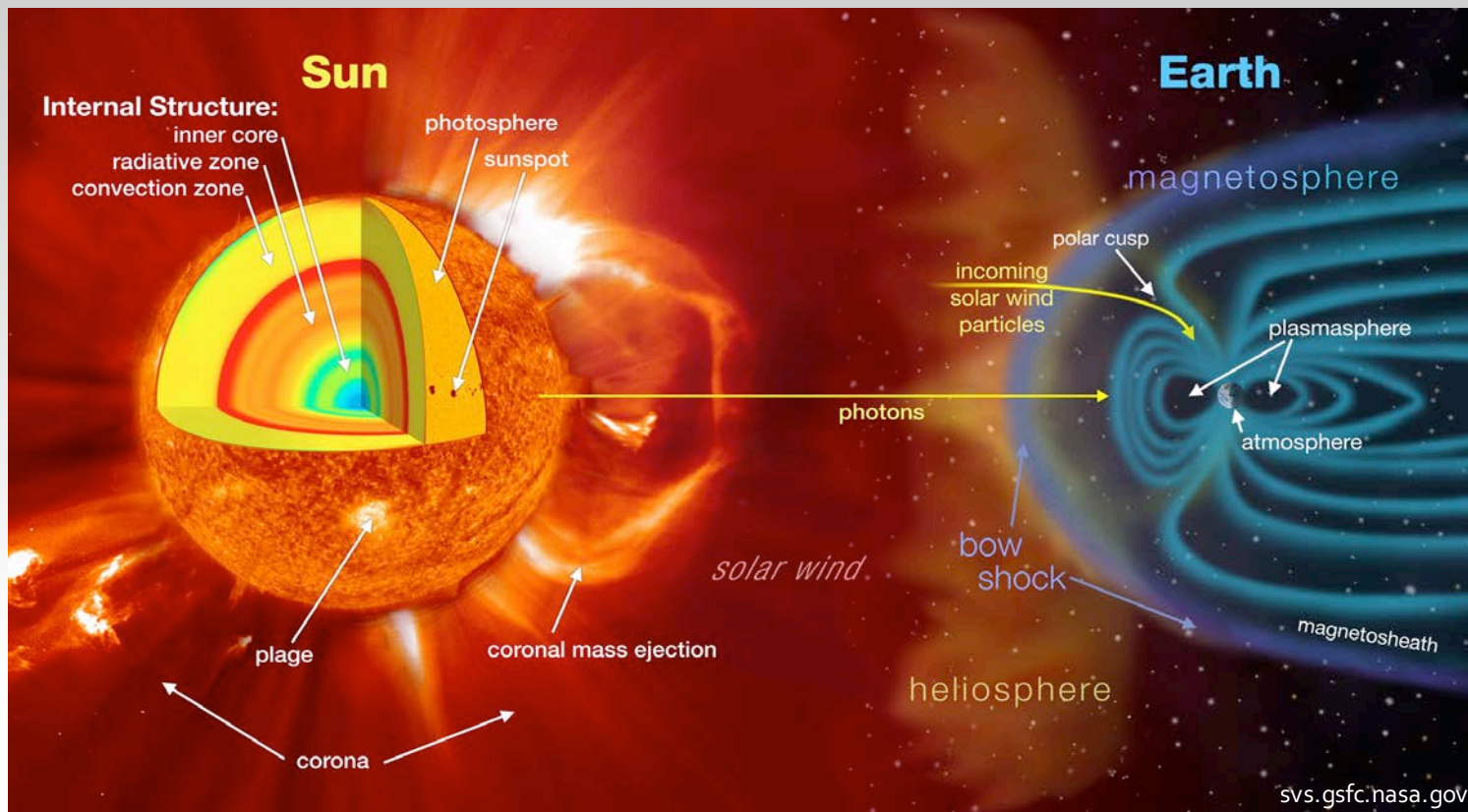


# Outline

- 1) Our Stellar Environment
  - Solar Wind
  - Magnetosphere
  - Magnetopause/Magnetosheath
- 2) Probes in the Solar Wind & Magnetosphere
  - Magnetospheric MultiScale (MMS) mission
  - Instruments on board
- 3) Solar Wind – Magnetosphere Interactions
  - Turbulence
  - Alfvén waves and Landau Damping
- 4) Looking at Turbulence in the Magnetosheath
  - Field aligned velocity distribution functions
  - Reduced distribution functions

# Our Stellar Environment

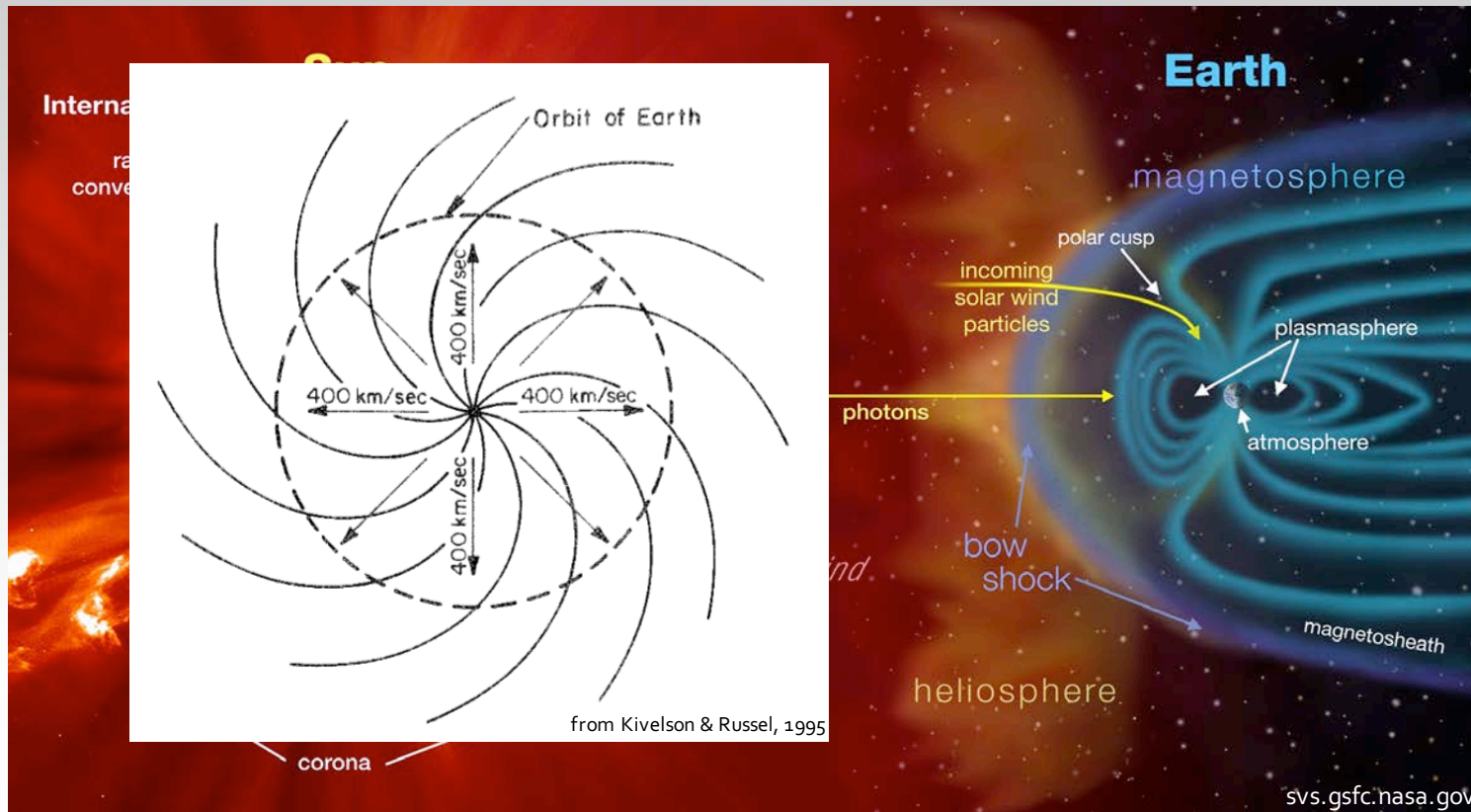
## The Solar Wind



- Composition
  - e's, ions: H, He
- Speed
  - 300 – 800 km/s
- Density
  - $1 - 10 / \text{cm}^3$

# Our Stellar Environment

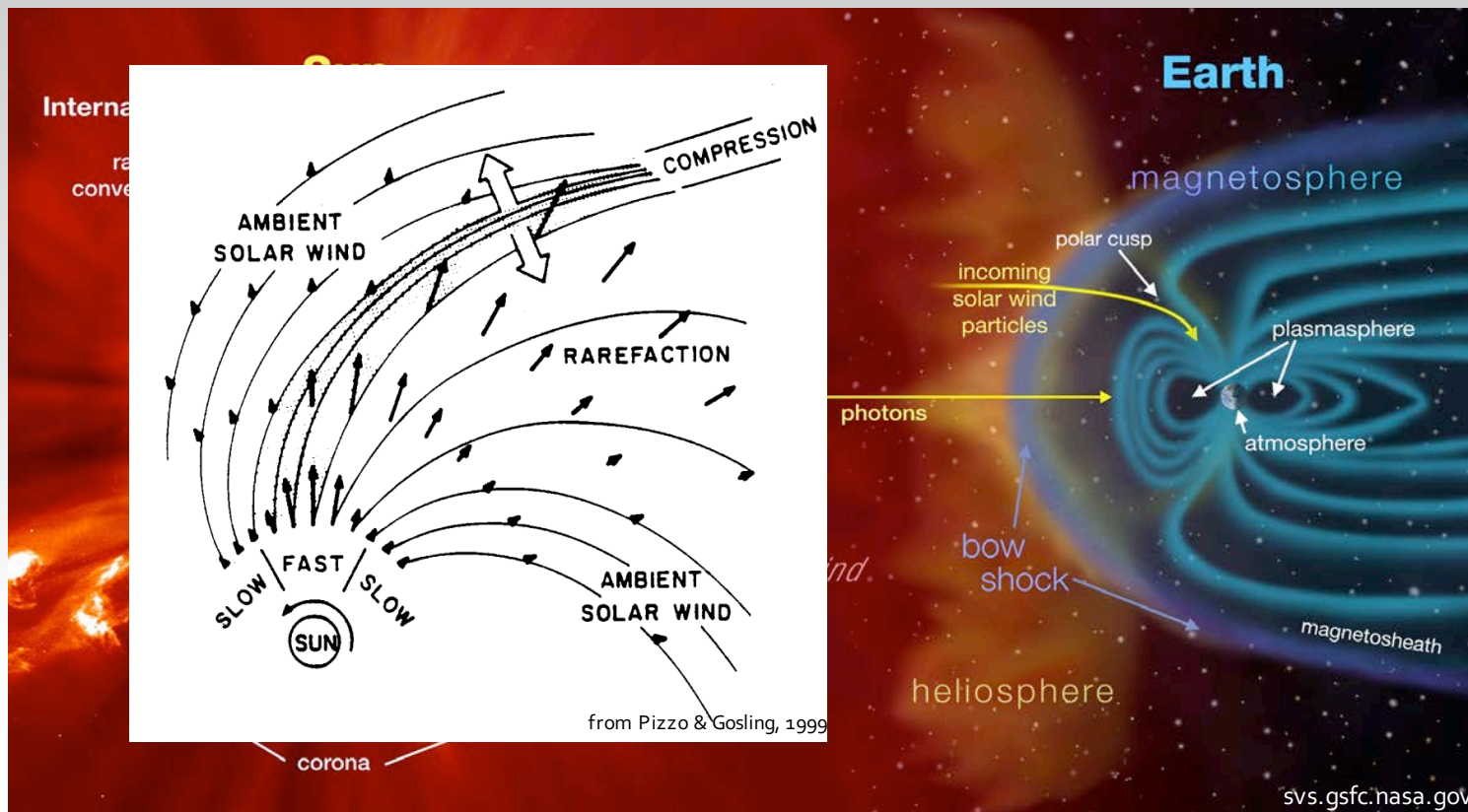
## The Solar Wind



- Composition
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# Our Stellar Environment

## The Solar Wind

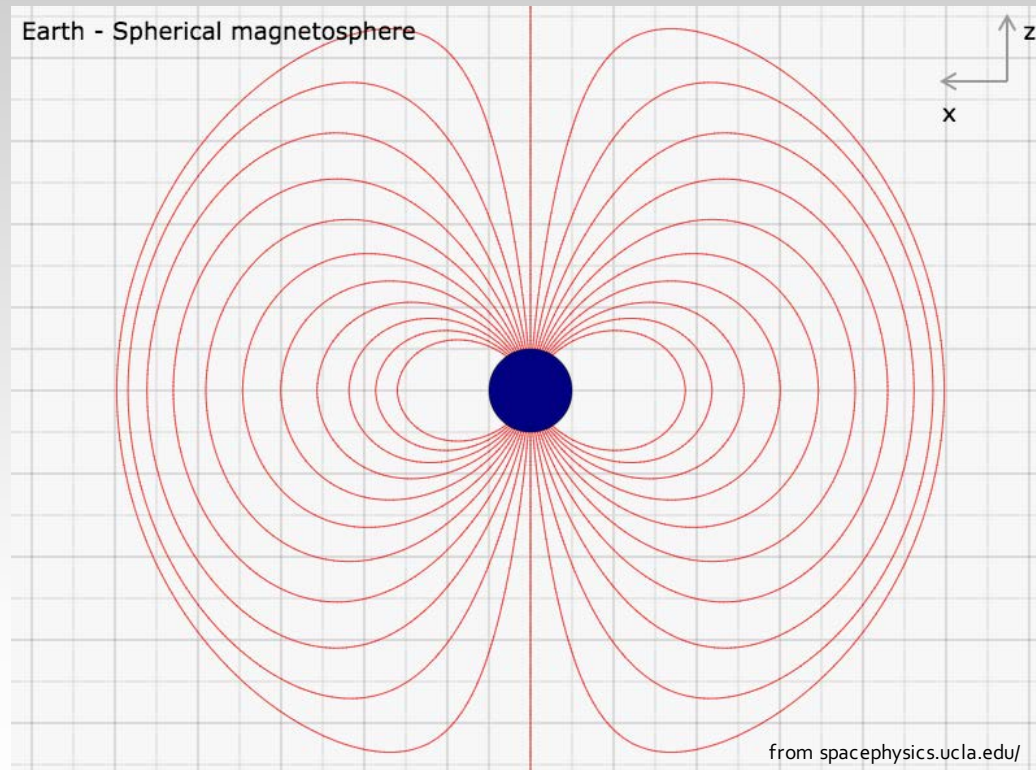


- Composition
  - e's, ions: H, He
- Speed
  - 300 – 800 km/s
- Density
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# Our Stellar Environment

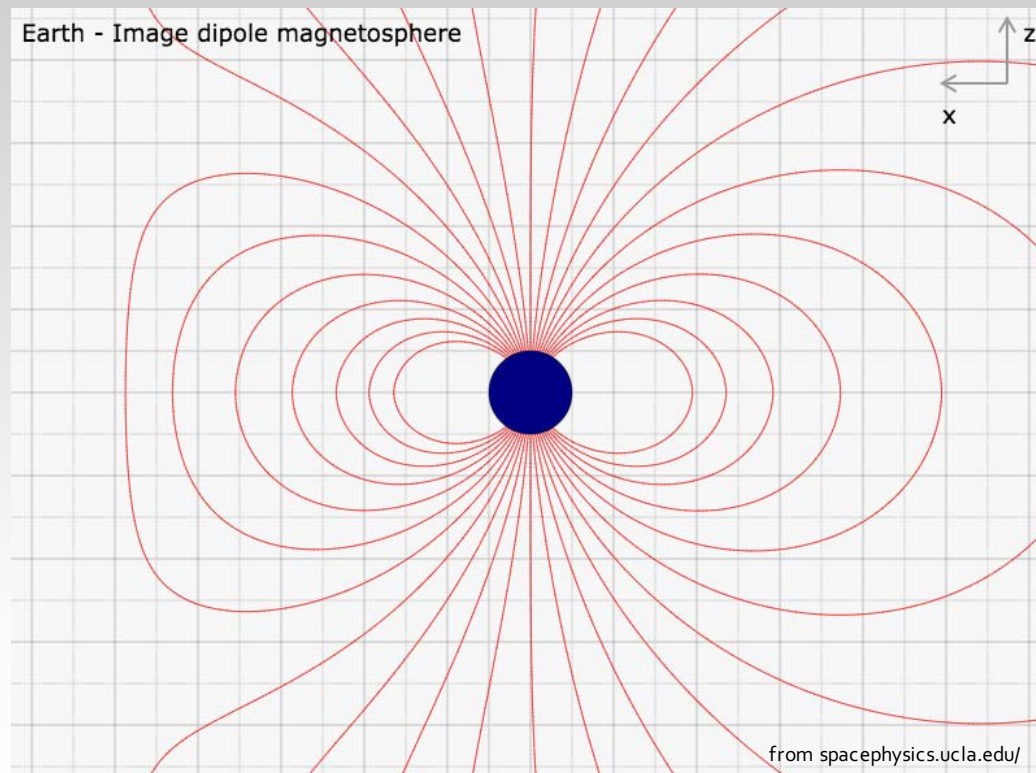
## The Magnetosphere



- Dipole
  - spherical

# Our Stellar Environment

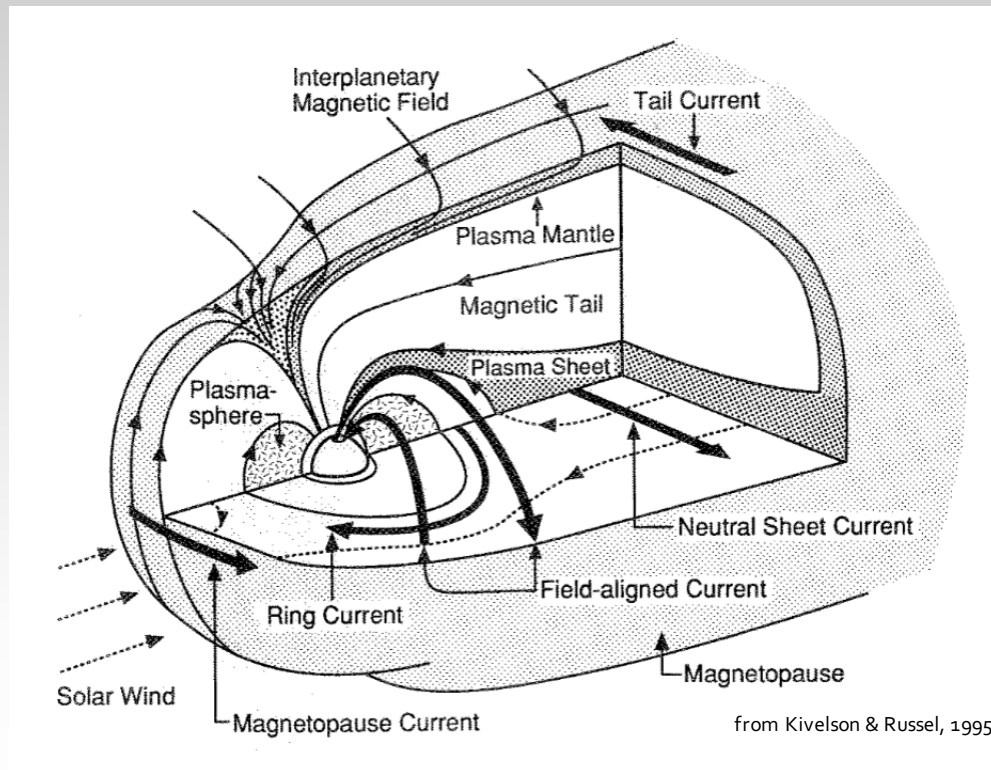
## The Magnetosphere



- Dipole
  - image

# Our Stellar Environment

## The Magnetosphere

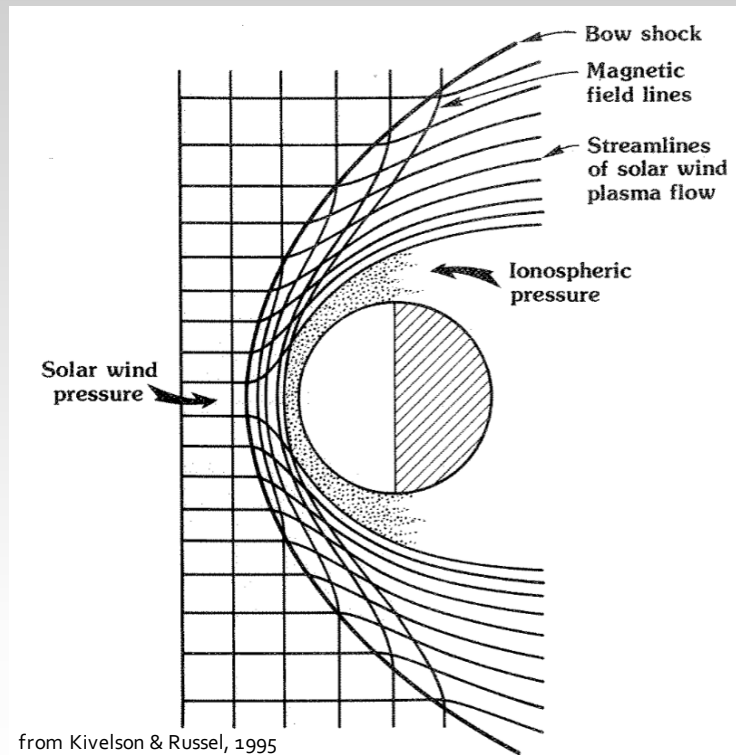


- Dipole
  - spherical
  - Image
  - nano-Tesla range
- Dayside effects and lengths
  - magnetic reconnection
  - 8 – 11 Re
- Nightside effects and lengths
  - magnetic reconnection
  - 10 – 60 Re
  - magnetotail



# Our Stellar Environment

## Magnetopause/Magnetosheath



- Bow shock
  - slows incoming particles
- Magnetosheath
  - turbulent mixing
- Magnetopause
  - terrestrial magnetic boundary

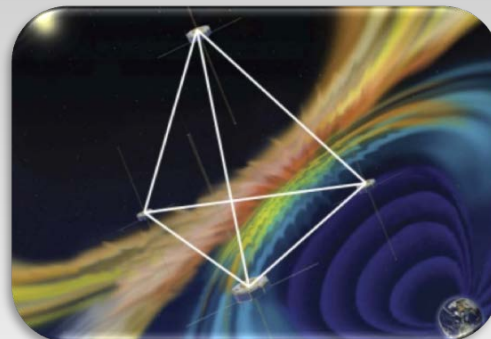
# Probes in the Solar Wind & Magnetosphere

## Magnetospheric MultiScale (MMS) mission

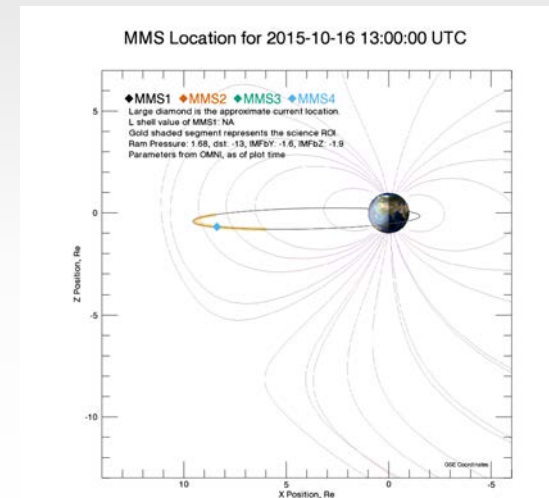
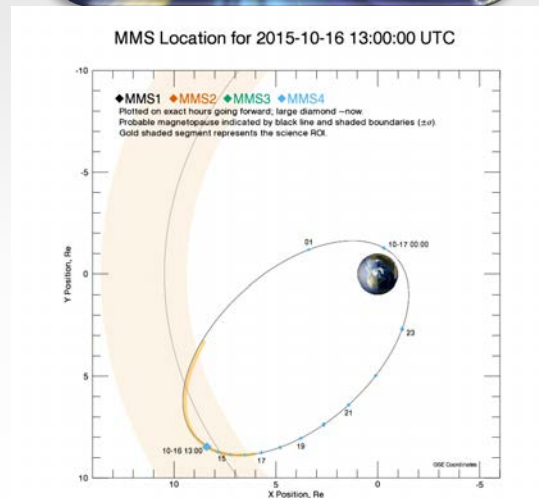


mms.gsfc.nasa.gov

University of Iowa

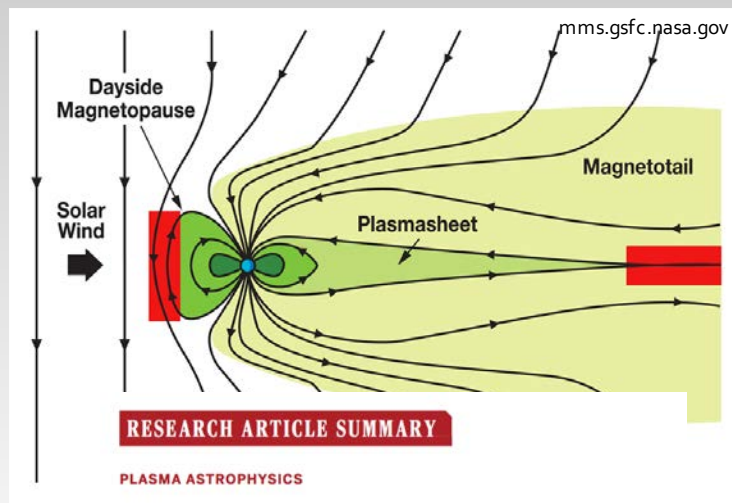


- SMART: Solving Magnetospheric Acceleration, Reconnection, and Turbulence
- Formation
  - tetrahedron
- Orbits
- Regions of interest (ROI)



A. S. Afshari

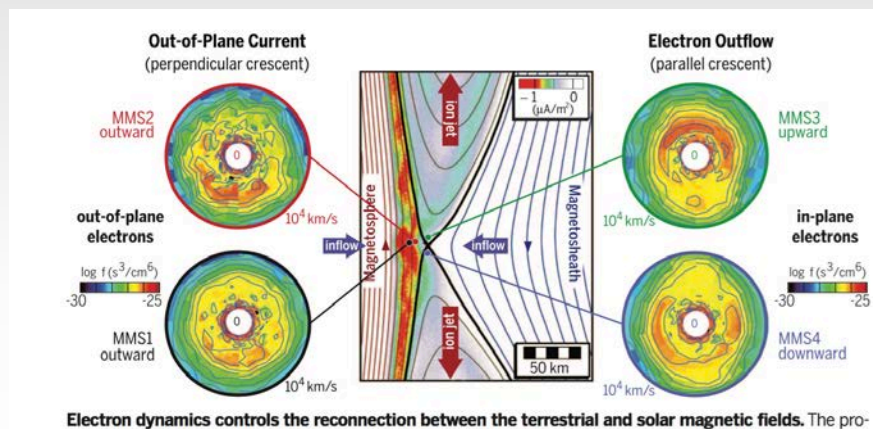
# Probes in the Solar Wind & Magnetosphere Magnetospheric MultiScale (MMS) mission



## Electron-scale measurements of magnetic reconnection in space

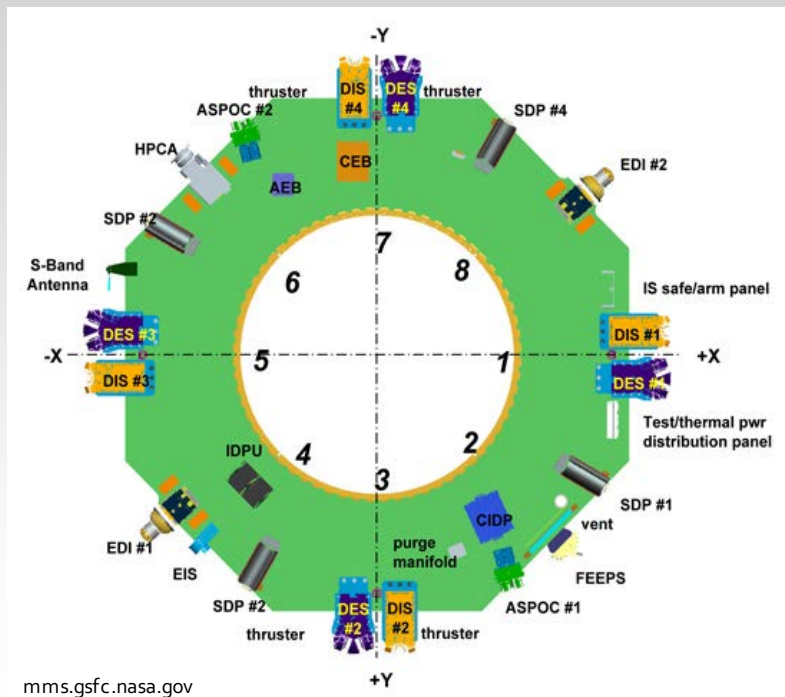
J. L. Burch,\* R. B. Torbert, T. D. Phan, L.-J. Chen, T. E. Moore, R. E. Ergun, J. P. Eastwood, D. J. Gershman, P. A. Cassak, M. R. Argall, S. Wang, M. Hesse, C. J. Pollock, B. L. Giles, R. Nakamura, B. H. Mauk, S. A. Fuselier, C. T. Russell, R. J. Strangeway, J. F. Drake, M. A. Shay, Yu. V. Khotyaintsev, P.-A. Lindqvist, G. Marklund, F. D. Wilder, D. T. Young, K. Torkar, J. Goldstein, J. C. Dorelli, L. A. Avanov, M. Oka, D. N. Baker, A. N. Jaynes, K. A. Goodrich, I. J. Cohen, D. L. Turner, J. F. Fennell, J. B. Blake, J. Clemmons, M. Goldman, D. Newman, S. M. Petrinec, K. J. Trattner, B. Lavraud, P. H. Reiff, W. Baumjohann, W. Magnes, M. Steller, W. Lewis, Y. Saito, V. Coffey, M. Chandler

- 03 June 16 issue of Science
- Evidence of magnetic reconnection



# Probes in the Solar Wind & Magnetosphere

## Instruments aboard MMS

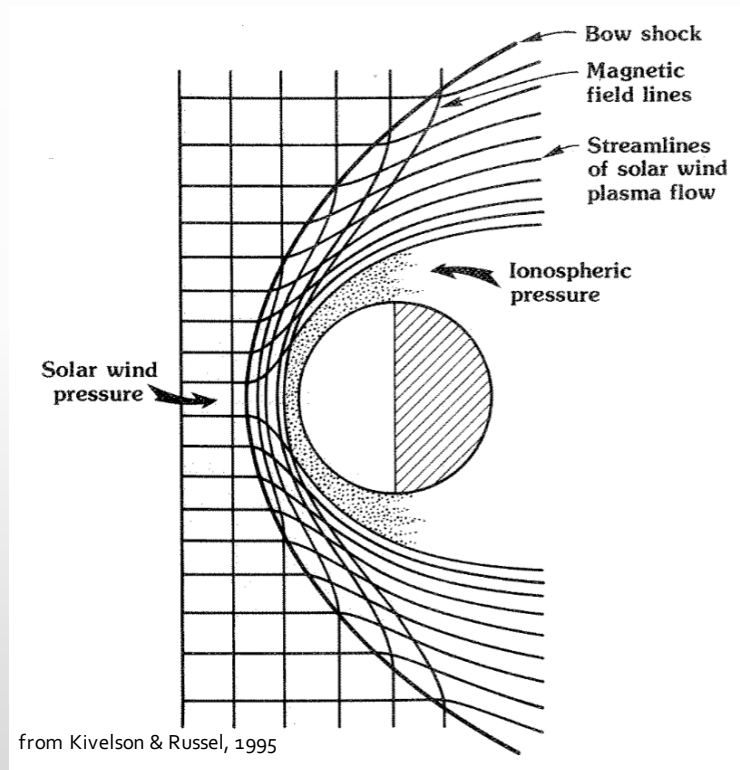


Each observatory is identically equipped with the following instruments:

- Dual ion/electron spectrometer (DIS/DES)
  - 150 ms (DIS), 30 ms (DES) , 10 – 30000 eV
- Flux gate magnetometer (FGM)
  - 128 Hz
- Fly's eye energetic particle sensor (FEEPS)
  - 10 s, 25 – 500 keV (ions), 45 – 500 keV (e's)
- Electron ion spectrometer (EIS)
  - 30 s, 45 – 500 keV
- Electron drift instrument (EDI)
- Active spacecraft potential control (ASPOC)
  - neutralizes the sc's electrical potential
- Hot plasma composition analyzer (HPCA)
  - 15 s, 10 – 30000 eV

# Solar Wind – Magnetosphere Interactions

## Magnetopause/Magnetosheath



- Bow shock
- Pressure balance:

$$\underbrace{\rho v^2 + nkT + \frac{B^2}{2\mu_0}}_{\text{solar}} = \underbrace{\frac{B^2}{2\mu_0} + nkT}_{\text{terrestrial}}$$

- Bulk motion -> thermal energy



# Looking at Turbulence in the Magnetosheath Nature

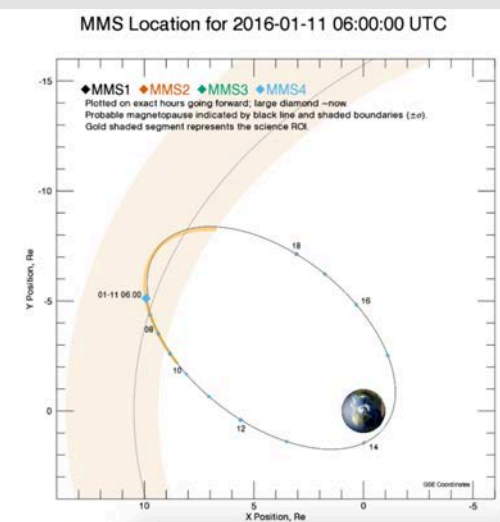
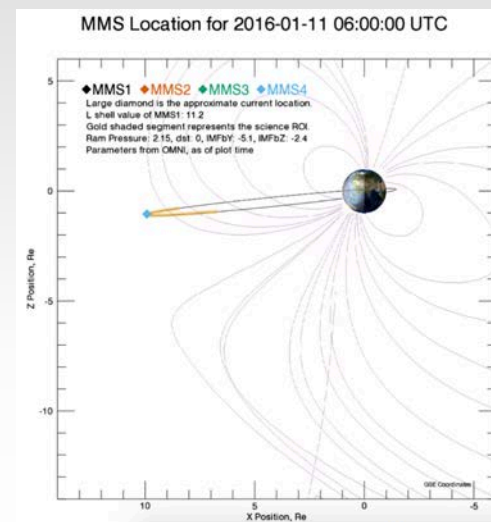
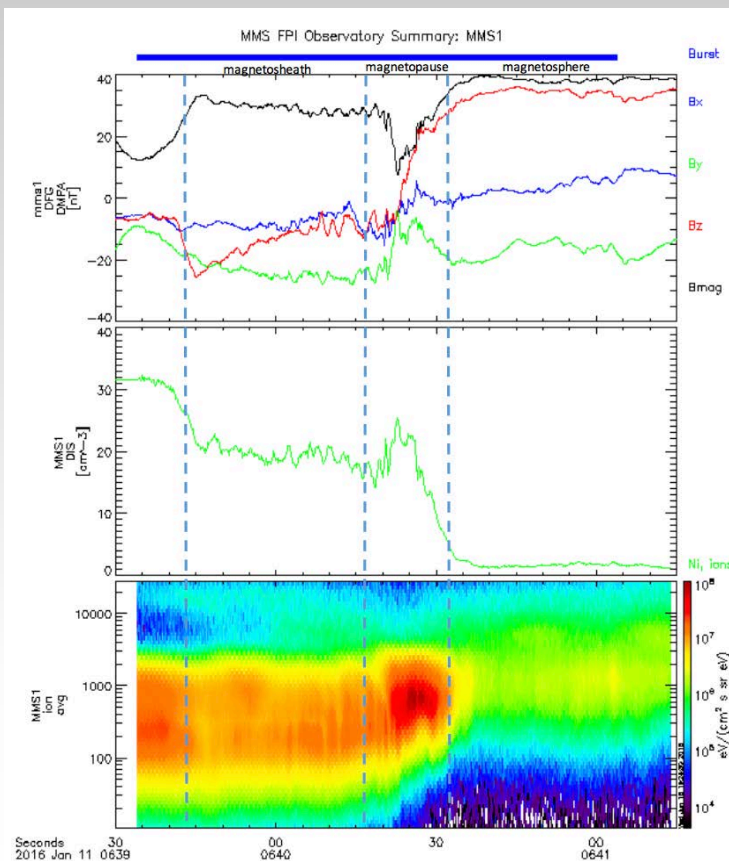


- Kelvin – Helmholtz Instability
- Kolmogorov spectrum

# Solar Wind – Magnetosphere Interactions

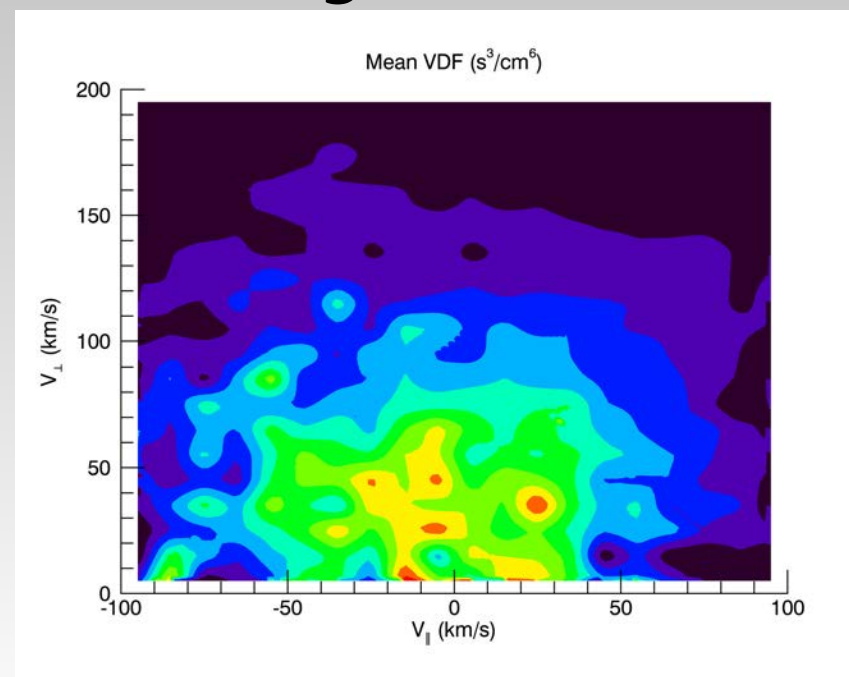
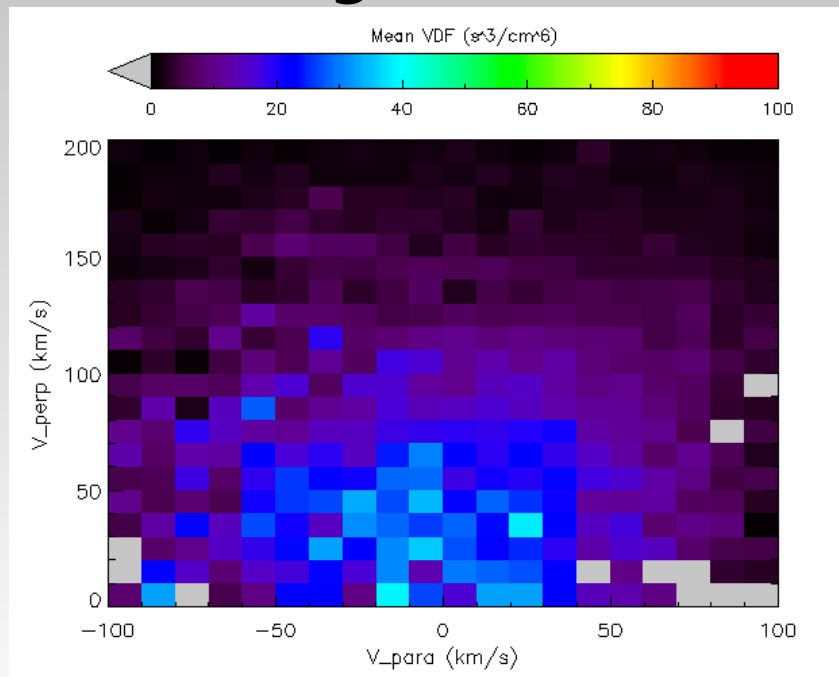
## Turbulence

- Particle turbulence: density fluctuations
- Magnetic field turbulence: fluctuations in magnitude of magnetic field
- Magnetopause crossing



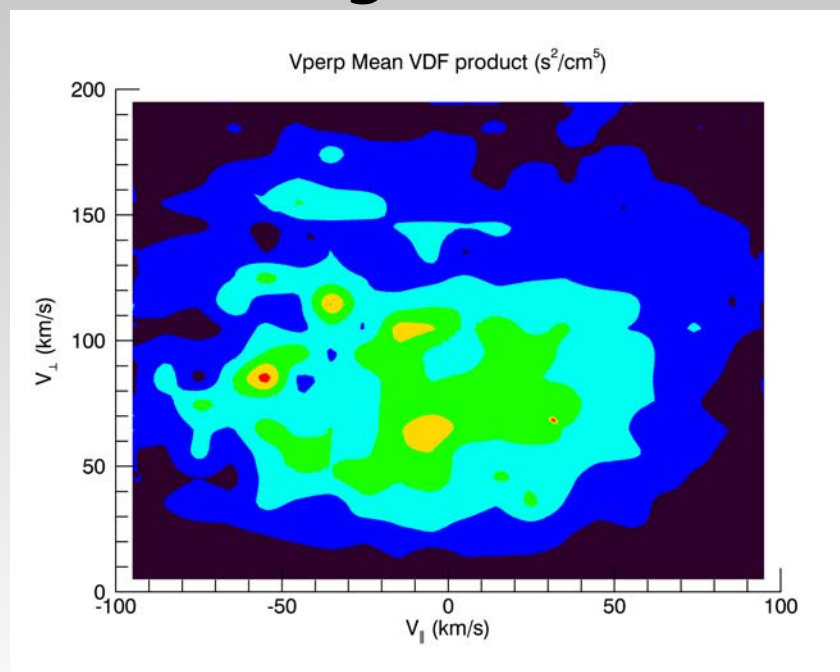
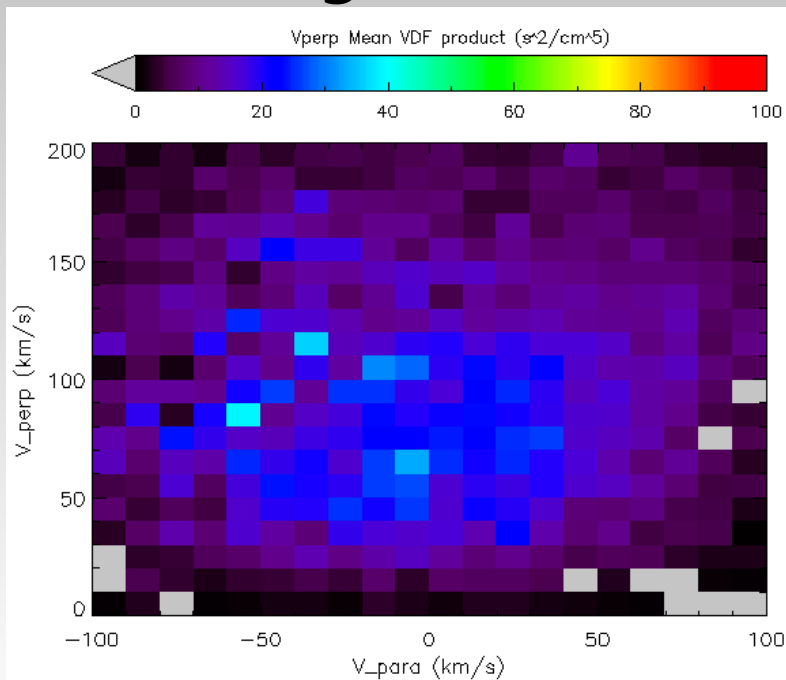
Source: <https://lasp.colorado.edu/mms/sdc/public/historical-orbit-plots/>

# Looking at Turbulence in the Magnetosheath



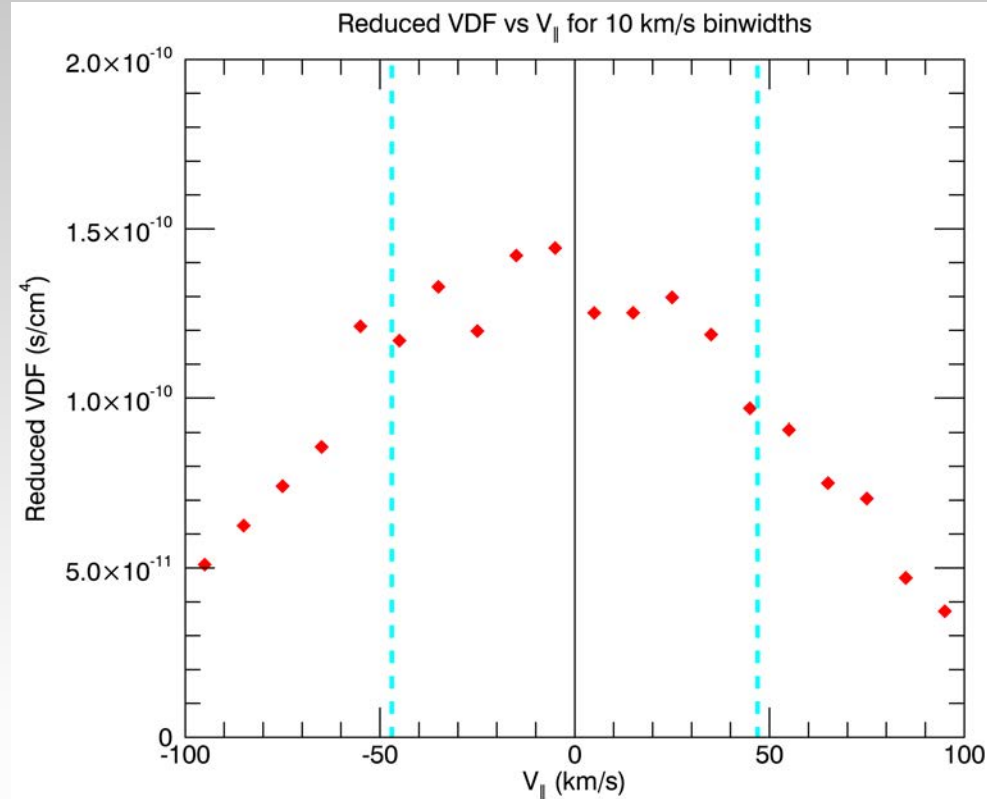
- MMS DIS distributions are converted from spherical to Cartesian coordinates and shifted to the plasma frame
- Field aligned velocity distribution functions (VDF):  $f(v_{\parallel}, v_{\perp})$
- Average distributions in 10 km/s binwidths

# Looking at Turbulence in the Magnetosheath



- Scaled VDF:  $f(v_{\parallel}, v_{\perp}) * v_{\perp}$

# Looking at Turbulence in the Magnetosheath



- Reduced VDF:  $g(v_{\parallel}) = \int f(v_{\parallel}, v_{\perp}) * v_{\perp} * dv_{\perp} * d\phi$ 
  - $g(v_{\parallel}) = 2\pi * \Delta v_{\perp} * \sum f(v_{\parallel}, v_{\perp}) * v_{\perp}$



# Future Work

- Incorporate statistical error
- Background VDF over a specified time
- Fluctuations of VDFs from background
- Fluctuations of magnetic field
- Correlate fluctuations of VDFs with those of magnetic field

# Summary

- Solar wind and magnetopause characteristics
- Magnetosphere MultiScale mission
- Turbulence and turbulence analysis

# Thank you!

- Nathaniel A. Frissell, HamSCI
- Professor Craig Kletzing, advisor
- C. Pollock, B. Giles, et al., MMS' FPI team